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Timber Resources of Babelthuap, Republic of Palau

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Cover: Upland forest, and savanna in foreground.

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CONTENTS

Introduction 1
Inventory Procedures 1
Reliability of Inventory Data 2
Results 2
Appendix—Tables 2
Glossary 8
References 8

INTRODUCTION

The Republic of Palau lies 800 kilometers (500 statute mi) east of the Philippine Islands and an equal distance north of the Equator, on the western edge of the Caroline Islands (lat. 7°20'N. and long. 134°28'E.) *(fig. 1)*. Although the Republic of Palau includes four volcanic high islands and numerous coral limestone islands, this inventory of forest resources was restricted to Babelthuap, the largest island in the group and the only one with extensive timberland area.

Information on timber volume and forest land was developed by combining data from vegetation type maps with observation and measurements collected on a grid of field plots. The vegetation type maps were the product of earlier studies (Cole and others 1987).

This bulletin reports results of an inventory of timber resources in Babelthuap, Republic of Palau, by the USDA Forest Services's Pacific Northwest and Pacific Southwest Forest and Range Experiment Stations, the Peace Corps, and the Government of Palau.

INVENTORY PROCEDURES

The inventory was designed to determine the area of land suitable for the production of industrial wood (i.e., timberland) and to estimate the volume of timber present. The field inventory was limited to forest land believed to be potentially capable of growing timber. Lands mapped as nonforest, secondary vegetation, or agroforest were not sampled. The sample was further restricted by excluding lands mapped as atoll forest, dwarf forest, or size class "0" (incapable of growing stands of trees larger than 12.5 cm in d.b.h.) on the assumption that these lands were "other forest" not capable of growing 1.4 cubic meters per hectare (20 ft³/acre) per year of industrial wood. The location and area of the forest land types were available from type maps prepared for an earlier study (Cole and others 1987).

The inventory design approximated stratified random sampling as described by Cochran (1963), but plots were selected on a square grid. Five strata were identified, including three forest types—upland forest, mangrove, and lowland swamp. Upland forest was further subdivided into three strata that differed in d.b.h. and density. The area of each stratum was measured from the type maps, thus providing a means of expanding plot data from the per hectare level to the stratum level. A square grid was laid out across the entire island. Each grid intersection that fell in one of the five timberland strata was selected as a field plot. The grid identified 49 such plots. All selected plots were pinpricked on aerial photos and located on the ground.

One plot from the timberland sample was found by ground examination to be secondary vegetation and another was found to be converted to nonforest use. The other 47 plots were found to still be timberland. Each timberland field plot was carefully located from the pinprick on the aerial photographs and permanently referenced for future remeasurement. At each location,

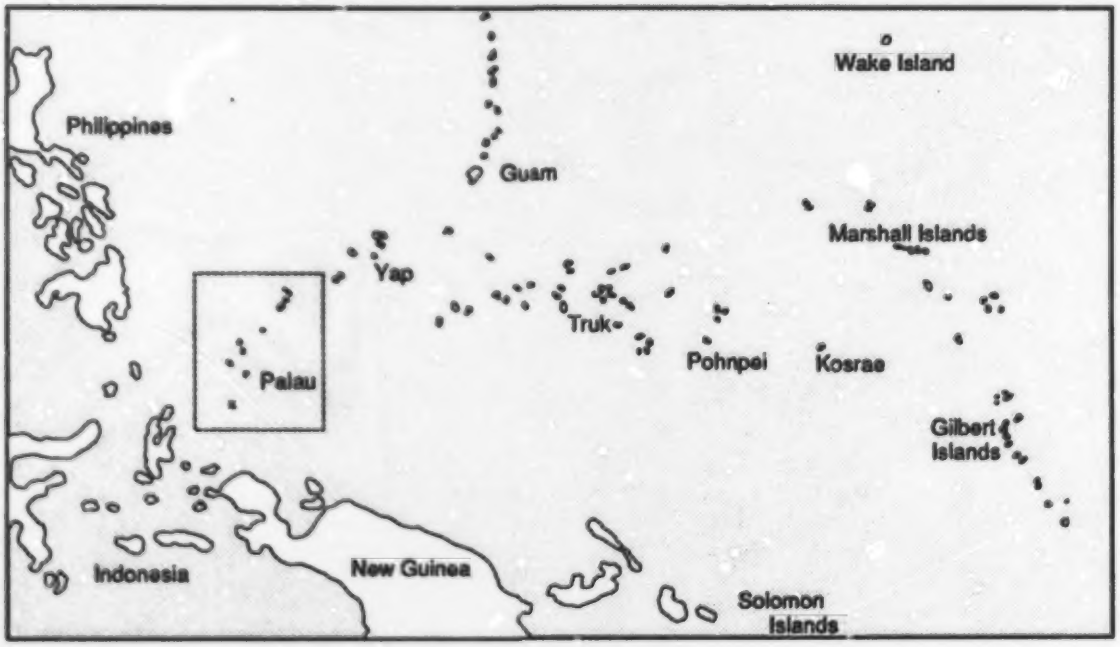

Figure 1—The Republic of Palau lies at the western end of the Carolineisland group.

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a cluster of five sample points was established, with the points distributed over about 2.5 hectares (6 acres). At each point, all trees with d.b.h. between 12.5 and 90 centimeters (5 and 35 in) were tallied if they were "in" with a metric 7-factor (English 30.5-factor) prism sample (Grosenbaugh 1958). In addition, all trees that were larger than 90 centimeters (35 in) in d.b.h. and within 17 meters (55.8 ft) of plot center were tallied, as were trees less than 12.5 centimeters (5 in) in d.b.h. and within 2.36 meters (7.7 ft) of plot center.

Species, d.b.h., and total height were recorded for each tree tallied. In addition, each tree was visually divided into logical segments and length and end diameters of these segments were measured or estimated. Each segment was identified either as a sawlog, poletimber, roughwood, an upper stem, a craftwood bolt, a crotch, a tip, or a branch. Rotten segments were identified as cull and trees with less than 25 percent sound wood were identified as rotten culls. With these measurements, it was possible to calculate the sound cubic volume in each segment of each tally tree, enabling us to report tree volume by class of material.

Each sample point was marked and referenced and each tally tree was tagged and numbered to facilitate relocation and remeasurement. Thus, when the plots are revisited, measurements of height and d.b.h. growth and tree mortality will be possible.

RELIABILITY OF INVENTORY DATA

Forest area statistics based on the type maps are without sampling error, although unknown amounts of technique error may be present. But, estimates of timberland area on Babelthuap were developed by multiplying the mapped timbered area by the proportion of field plots that proved to be timberland—not nonforest nor secondary vegetation. Estimates of timberland area for strata where the estimated proportion of timberland was less than 1 but greater than 0, were subject to sampling error. If, however, all plots in a given stratum—e.g., mangrove—were timberland, the estimated area for that stratum was without sampling error. Thus, the estimate of timberland area in upland forest types on Babelthuap is subject to sampling error, while the estimates of timberland area in mangrove and swamp forest type are without sampling error. Since estimates of volume are derived from sample measurements, they are all subject to sampling error. Confidence intervals for estimates of area-volume (68 percent probability level) are as follows:

Forest type	Timberland area *Hectares*	Net volume *1,000 m^3*
Upland	20,058 ± 676	2,511 ± 203
Mangrove	3,566 ± 0	206 ± 71
Swamp	1,613 ± 0	231 ± 61
All types	25,261 ± 676 (62,420 ± 1,670)[1]	2,948 ± 224 (104,108 ± 7,910)[2]

[1]Acres.
[2]1,000 ft^3.

Confidence intervals are quantitative expressions of the reliability of the timberland area and volume statistics. The above tabulation, for example indicates a two-in-three chance that there are abetween 24,600 and 25,900 hectares (61,000 and 64,000 acres) of timberland on the island of Babelthuap, and between 2.724 and 3.172 million cubic meters (96 and 112 million ft^3) of timber volume.

RESULTS

- This forest inventory of Babelthuap covered 36,733 hectares (90,767 acres), of which 25,261 hectares (62,420 acres) were timberland *(table 1)*. (All tables are in the *appendix*).
- The upland forest type occupied most of the forest land—20,703 hectares (51,157 acres) *(table 2)*.
- The volume of standing timber was an estimated 2.9 million cubic meters (104.1 million ft^3), of which an estimated 2.5 million cubic meters (88.7 million ft^3) were in the upland forest type *(table 3)*.
- *Campnosperma brevipetiolata* is the species with the most timber volume—370,000 cubic meters (13 million ft^3) *(table 4)*.
- The tree species found most frequently on the sample test plots were *Pinanga insignis, Parinari corymbosa, Semecarpus venenosus,* and *Campnosperma brevipetiolata (table 5)*.
- *Campnosperma brevipetiolata* and *Horsfieldia amklaal* account for 30 percent of the estimated 1,176,000 cubic meters (40 million ft^3) of timber volume *(table 6, 7)*.
- The volume of tree fern *(Cyathea lunulata* [Forst. f.] Copel. [Cyatheaceae]) is 43,000 cubic meters (1,519,000 ft^3), all in the upland forest type.

APPENDIX—TABLES

Table 1—*Area by land class, Babelthuap, Republic of Palau, 1985*

Land class	Area	
	Hectares (acres)	
Forest land:		
Timberland	25,261	(62,420)
Other forest:		
Steep[1]	104	(257)
Scrub[2]	1,108	(2,738)
Total[3]	26,473	(65,415)
Secondary vegetation	1,008	(2,491)
Agroforest	924	(2,283)
Nonforest	8,328	(20,578)
All lands	36,733	(90,767)

[1]Land supporting stands of timber species but considered unsuitable for the production of continuous crops of timber because of slopes greater than 100 percent (45°).
[2]Sites believed incapable of growing trees of size and form suitable for commercial use.
[3]Reduced by 987 hectares to account for land converted to nonforest and secondary vegetation since completing the vegetation map.

Table 2—*Area of forest land by forest type and land class, Babelthuap, Republic of Palau, 1985*

Forest type	Land class			
	Timberland	Other forest (steep)[1]	Other forest (scrub)[2]	Total forest
	Hectares (acres)			
Upland	20,038	—	645	20,703 (51,157)
Mangroves	3,566	—	459	4,025 (9,946)
Swamp	1,613	—	4	1,617 (3,995)
Plantation	24	—	–	24 (60)
Rock Island	—	104	—	104 (257)
All types	25,261	104	1,108	26,473 (65,415)

[1]Land supporting stands of timber species but considered unsuitable for the production of continuous crops of timber because of slopes in excess of 100 percent.
[2]Sites believed incapable of growing trees of size and form suitable for commercial use.

Table 3—*Volume of timber on timberland by tree component and forest type, Babelthuap, Republic of Palau, 1985*

Tree component	Forest type			
	Upland forest	Mangrove forest	Swamp forest	All types
	1,000 m³ (1,000 ft³)			
Sawtimber:				
Saw log	981	27	126	1,134 (40,047)
Upper stem	168	13	19	200 (7,063)
Craftwood bolts	60	16	1	77 (2,719)
Branch and crotch	123	7	5	135 (4,767)
Tip	16	1	1	18 (636)
Roughwood	156	19	8	183 (6,463)
Total	1,504	83	160	1,747 (61,695)
Poletimber:				
Poletimber	855	105	41	1,001 (35,350)
Tip	62	6	4	72 (2,543)
Branch	90	12	26	128 (4,520)
Total	1,007	123	71	1,201 (42,413)
Total volume	2,511	206	231	2,948 (104,108)

Table 4—*Total volume on timberland by species and forest type, Babelthuap, Republic of Palau, 1985*[1]

Species and family[2]	Forest type			All types	
	Upland forest	Mangrove forest	Swamp forest		
	1,000 m³ (1,000 ft³)				
Alphitonia carolinensis Hosok. (Rhamnaceae)	151	—	—	151	(5,333)
Astronidium palauense (Kanch.) Mgf. (Melastomataceae)	4	—	—	4	(141)
Barringtonia racemosa (L.) Spreng. (Lecythidaceae)	22	—	—	22	(777)
Bruguiera gymnorhiza (L.) Lam. (Rhizophoraceae)	—	16	—	16	(565)
Calophyllum inophyllum L.[3] (Guttiferae)	121	—	—	121	(4,273)
Campnosperma brevipetiolata Volk. (Anacardiaceae)	358	—	12	370	(13,066)
Canthium rupestre Hosok. (Rubiaceae)	27	—	—	27	(953)
Cerbera spp. L. (Apocynaceae)	32	—	—	32	(1130)
Ceriops tagal (Perr.) C.B. Rob. (Rhizophoraceae)	—	6	—	6	(212)
Cocos nucifera L. (Palmae)	42	—	100	142	(5,000)
Colona scabra (Sm.) Burret (Tiliaceae)	36	—	—	36	(1,285)
Dracaena multiflora Warb. ex Sarasin (Agavaceae)	10	—	—	10	(346)
Elaeocarpus joga Merr. (Tiliaceae)	36	—	—	36	(1,275)
Eugenia spp. L. (Myrtaceae)	18	—	3	21	(756)
Fagraea hsid Gig & Benod. (Gentianaceae)	58	—	—	58	(2,048)
Flagellaria indica L. (Flagellariaceae)	6	—	2	8	(931)
Garcinia ramiflora var. calcicola Fosb. (Guttiferae)	21	—	8	29	(1,021)
Gmelina palawensis J.H. Lam (Verbenaceae)	124	—	13	137	(4,838)
Horsfieldia amblasi Kanch. (Myristicaceae)	206	—	26	232	(8,193)
Horsfieldia novo-guineensis Warb. (Myristicaceae)	93	—	—	93	(3,277)
Horsfieldia palauensis Kanch. (Myristicaceae)	37	—	3	40	(1,409)
Inocarpus fagifer (Park.) Fosb. (Leguminosae)	27	—	—	27	(968)
Kentrochrosia carolinensis (Kanch.) Kanch. & Hatus.	35	—	4	39	(1,377)

(continued)

Table 4—*Total volume on timberland by species and forest type, Babelthuap, Republic of Palau, 1985*[1] *(continued)*

Species and family[2]	Forest type			All types	
	Upland forest	Mangrove forest	Swamp forest		
	1,000 m³ (1,000 ft³)				
(Apocynaceae)					
Lumnitzera littorea (Jack) Voigt	—	75	—	75	(2,649)
(Combretaceae)					
Macaranga carolinensis Volk.	5	—	4	10	(339)
(Euphorbiaceae)					
Manilkara udoido Kaneh.	48	—	—	48	(1,695)
(Sapotaceae)					
Merremia spp. Dennst. ex Hall. f.	13	—	—	13	(470)
(Convolvulaceae)					
Morinda latifoliacteata Val.	7	—	—	7	(251)
(Rubiaceae)					
Ophiorrhiza palauensis Val.	32	—	—	32	(1,126)
(Rubiaceae)					
Parinari corymbosa (Bl.) Miq.	318	—	10	328	(11,569)
(Rosaceae)					
Parinari laurina Gray	51	—	—	51	(1,812)
(Rosaceae)					
Pinanga insignis Becc.	198	—	17	215	(7,589)
(Palmae)					
Pouteria obovata (R. Br.) Baehni	31	—	—	31	(1,098)
(Sapotaceae)					
Pterocarpus indicus Willd.	52	—	8	60	(2,112)
(Leguminosae)					
Rhizophora mucronata Lam.	—	46	—	46	(1,624)
(Rhizophoraceae)					
Rhus taitensis Guill.	95	—	4	99	(3,500)
(Anacardiaceae)					
Semecarpus venenosus Volk.	43	—	3	46	(1,624)
(Anacardiaceae)					
Serianthes kanehirae Fosb.	7	—	11	18	(635)
(Leguminosae)					
Sonneratia alba J. E. Sm.	—	54	—	54	(1,907)
(Sonneratiaceae)					
Symplocos racemosa var. *palauensis* (Koidz.) Noot.sb.	45	—	—	45	(1,596)
(Symplocaceae)					
Trichospermum ledermannii Burret	23	—	—	23	(812)
(Tiliaceae)					
Vitex cofassus Reinw. ex Bl.	15	—	—	15	(530)
(Verbenaceae)					
Xylocarpus granatum Koen.	—	9	—	9	(318)
(Meliaceae)					
Others	64	—	2	66	(2,649)
All species	2,511	206	231	2,948	(104,108)

[1]Totals may vary because all volume estimates are rounded.
[2]Source: Fosberg and others (1980).
[3]Includes *C. inophyllum* var. *inophyllum* and var. *walkeriatus*.

Table 5—*Frequency of occurrence of individual species by forest type, Babelthuap, Republic of Palau, 1985*

Species	Forest type (numbers of plots)			All types (49)
	Upland forest (41)	Mangrove forest (5)	Swamp forest (3)	
	Proportion of plots where species occurred			
Alphitonia carolinensis	0.439	.000	.000	0.367
Astronidium palauense	.122	.000	.000	.102
Barringtonia racemosa	.098	.000	.000	.082
Bruguiera gymnorhiza	.000	.600	000	.061
Calophyllum inophyllum	.220	.000	.000	.184
C. inophyllum var. *wakamatsui*	.171	.000	.000	.143
Campnosperma brevipetiolata	.610	.000	.333	.531
Canthium rupestre	.122	.000	.000	.102
Carbera spp.	.171	.000	.000	.143
Ceriops tagal	.000	.600	.000	.061
Cocos nucifera	049	.000	.667	.082
Colona scabra	.098	.000	.000	.082
Dracaena multiflora	.146	.000	.333	.143
Elaeocarpus joga	.220	.000	.000	.184
Eugenia spp.	.585	.000	.667	.531
Fagraea knid	.171	.000	.000	.143
Flagellaria indica	.122	.000	.333	.122
Garcinia rumiyo var. *calcicola*	.244	.000	.333	.224
Gmelina palawensis	.439	.000	.333	.388
Horsfieldia amblaal	.390	.000	.333	.347
Horsfieldia novo-guineensis	.098	.000	.000	.082
Horsfieldia palauensis	.244	.000	.333	.224
Inocarpus fagifer	.122	.000	.000	.102
Xenthrochrasia carolinensis	.098	.000	.333	.102
Lumnitzera littorea	.000	.400	.000	.041
Macaranga carolinensis	.195	.000	.667	.204
Manilkara udoido	.195	.000	.000	.163
Merremia spp.	.049	.000	.000	.041
Morinda latibracteata	.171	.000	.000	.143
Ophiorrhiza palauensis	.171	.000	.000	.143
Parinari corymbosa	.659	.000	.333	.571
Parinari laurina	.171	.000	.000	.143
Pinanga insignis	.683	.000	.667	.612
Pouteria obovata	.245	.000	.000	.204
Pterocarpus indicus	.122	.000	.333	.122
Rhizophora mucronata	.000	1.000	.000	.102
Rhus taitensis	.390	.000	.333	.347
Semecarpus venenosus	.610	.000	.333	.531
Serianthes kanehirae	.024	.000	.333	.041
Sonneratia alba	.000	.200	.000	.020
Symplocos racemosa var. *palauensis*	.171	.000	.000	.143
Trichospermum ledermannii	.146	.000	.000	.122
Vitex cofassus	.024	.000	.000	.020
Xylocarpus granatum	.000	.800	.000	.082

Table 6—*Volume of timber on timberland by tree component for eight upland and swamp species, Babelthuap, Republic of Palau, 1985*[1]

Tree component	Species[2]							
	CABR	CAIN	GMPA	HOAM	MAUD	PTIN	SEKA	VICO
	1,000 m³ (1,000 ft³)							
Sawtimber:								
Saw log	226	71	16	118	20	40	15	7
Upper stem	32	10	10	11	5	9	1	3
Craftwood bolts	9	4	3	4	—	1	—	1
Branch and crotch	18	9	9	9	4	4	2	1
Tip	3	1	1	1	1	1	—	—
Roughwood	19	15	18	12	3	5	—	3
Total	307	110	57	153	43	60	18	15
Poletimber:								
Poletimber	53	8	66	49	4	—	—	—
Tip	4	1	5	3	1	—	—	—
Branch	5	1	9	26	—	—	—	—
Total	63	11	80	78	5	—	—	—
Total volume	370 (13,031)	121 (4,273)	137 (4,838)	232 (8,193)	48 (1,695)	60 (2,119)	18 (635)	15 (530)

[1] Totals may vary because all volume estimates are rounded.

[2] CABR = *Campnosperma brevipetiolata*; CAIN = *Calophyllum inophyllum*; GMPA = *Gmelina palawensis*; HOAM = *Horsfieldia amklasi*; MAUD = *Manilkara udoido*; PTIN = *Pterocarpus indicus*; SEKA = *Serianthes kanehirae*; VICO = *Vitex cofassus*.

Table 7—*Volume of timber on timberland by tree component for three mangrove species, Babelthuap, Republic of Palau, 1985*[1]

Tree component	Species[2]		
	LULI	RHMU	SOAL
	1,000 m³ (1,000 ft³)		
Sawtimber:			
Saw log	15	—	12
Upper stem	8	—	5
Craftwood bolts	14	—	2
Branch and crotch	4	—	3
Tip	1	—	—
Roughwood	6	—	13
Total	48	—	35
Poletimber:			
Poletimber	24	38	17
Tip	1	2	1
Branch	2	6	1
Total	27	46	19
Total volume	75 (2,643)	46 (1,624)	54 (1,907)

[1] Totals may vary because all volume estimates are rounded.

[2] LULI = *Lumnitzera littorea*; RHMU = *Rhizophora mucronata*; SOAL = *Sonneratia alba*.

GLOSSARY

Agroforest: Land where planted fruit trees and other agricultural plants are cultured among forest trees.

Branches: Tree limbs not meeting sawlog or bolt specifications.

Craftwood bolts: Two-meter (6-ft) sections of trees that are at least 27.5 centimeters (11 in) in d.b.h. Must have mid-point diameters of at least 25 centimeters (10 in) and must not meet sawlog specifications.

Crotches: The swollen portions of tree stems at forks.

Cull: A volume deduction for rotten wood.

Cull trees, rotten: Trees that are more than 75 percent defective because of rot.

D.b.h. (diameter at breast height): Diameter at a point 1.3 meters (4.26 ft) above ground or the uphill side of normally formed trees or 0.5 meters (1.6 ft) above the butt swell of abnormally formed trees.

Forest land: Land at least 10 percent stocked by live trees or land formerly having such tree cover and not currently developed for nonforest or agroforest use.

Forest plantations: Planted forests in which at least 10 percent of growing space is occupied by planted trees.

Forest type: A vegetation type where the predominant cover is trees. Forest types recognized in this report are:

- **Atoll forests:** Associations of species generally occurring toward the interior of larger and wetter uninhabited atolls and on sandy or rocky coasts of low and high islands.
- **Dwarf forests:** Forests of small, poorly formed trees growing on an exposed site, generally at a high elevation.
- **Mangrove forests:** Forests where mangrove species predominate and tree roots are periodically inundated by sea water.
- **Palm forests:** Forest associations where native palms predominate.
- **Plantation forests:** Planted stands of timber species.
- **Swamp forests:** Forest associations found in low-lying fresh water areas inland of the mangroves, in river bottoms, and elsewhere where the water table is high.
- **Upland forests:** Forests where palms do not predominate and where the water table is too low to support mangrove or swamp forest species.

Grassland: Nonforest land with 10 percent or more herbaceous cover and not cultivated or developed for urban use.

Industrial wood: All commercial roundwood except fuelwood.

Land class: A classification of land by major use. The minimum size for area classification is 0.4 hectares (1 acre).

Net volume: Cubic volume, exclusive of rotten wood.

Nonforest land: Land that has never supported forests or land that formerly supported forests but is developed for nonforest use.

Other forest land: Forest land incapable of producing trees of merchantable size (>12.5 cm or 5 in) in d.b.h. because of adverse site conditions, or land that is physically unsuited for the production of continuous crops of industrial wood because of rocky or steep terrain.

Poletimber trees: Live trees that are between 12.5 centimeters (5 in) and 27.5 centimeters (11 in) in d.b.h.

Poletimber volume: The net cubic volume in poletimber trees.

Rough wood: Logs of sawtimber size that fail to meet saw-log specifications because of poor form or excessive limbs.

Saw-logs: Straight segments of sawtimber trees that are at least 2.5 meters (8.2 ft) long and no less than 22.5 centimeters (9 in) in diameter outside the bark at the small end.

Sawtimber trees: Live trees that are at least 27.5 centimeters (11 in) in d.b.h.

Sawtimber volume: The net cubic volume in sawtimber trees.

Secondary vegetation: A vegetation type characterized by small, fast-growing trees and vines, usually weedy invaders.

Stump: The portion of a tree that lies below a point 0.3 meters (1 ft) above the ground or, for a tree with a swollen or fluted butt, the portion that lies below the top of the swelling.

Timberland: Forest land capable of producing at least 1.4 cubic meters per hectare (20 ft^3/acre) per year of industrial wood and not withdrawn from timber utilization.

Timber volume: The net cubic volume of all poletimber and sawtimber trees, including tip and branches but excluding stump.

Tip: The portion of the main stem of a sawtimber or poletimber tree that is less than 10 centimeters (4 in) in diameter outside the bark.

Tree components: Segments of trees with specific utilization characteristics: bolts, branches, crotches, rough wood, saw logs, tips, upper stems.

Upper-stem: The bole of a sawtimber tree above the saw-log top—22.5 centimeters (9 in) outside the bark—to a minimum top diameter of 10 centimeters (4 in) outside the bark or to the point where the central stem breaks into limbs.

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The Forest Service, U.S. Department of Agriculture, is responsible for Federal leadership in forestry. It carries out this role through four main activities:

- Protection and management of resources on 191 million acres of National Forest System lands.
- Cooperation with State and local governments, forest industries, and private landowners to help protect and manage non-Federal forest and associated range and watershed lands.
- Participation with other agencies in human resource and community assistance programs to improve living conditions in rural areas.
- Research on all aspects of forestry, rangeland management, and forest resources utilization.

The Pacific Southwest Forest and Range Experiment Station

- Represents the research branch of the Forest Service in California, Hawaii, and the western Pacific.

MacLean, Colin D.; Cole, Thomas G., Whitesell, Craig G.; McDuffie, Katharine E. 1988. **Timber resources of Babelthuap, Republic of Palau.** Resour. Bull. PSW-23. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 8 p.

In a forest inventory of the island of Babelthuap, Republic of Palau, 36,733 hectares (90,767 acres) were surveyed, of which 25,261 hectares (62,420 acres) were timberland. This timberland has an estimated 2.9 million cubic meters (104.1 million ft³) of standing timber, of which an estimated 2.5 million cubic meters (88.7 million ft³) were found in the upland forest type, 206,000 cubic meters (7.3 million ft³) in the mangrove type, and 231,000 cubic meters (8.2 million ft³) in the swamp forest type.

Retrieval Terms: forest surveys, forest inventory, timber, Babelthuap, Babeldaob, Palau, Belau, Caroline Islands, Micronesia

(PALAUAN TRANSLATION)

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